NIE 11-2-57
7 May 1957
TS 117200

~~TOP SECRET~~

(b) (1)
(b) (3)

NATIONAL INTELLIGENCE ESTIMATE
NUMBER 11-2-57

THE SOVIET ATOMIC ENERGY PROGRAM

LIMITED DISTRIBUTION

Submitted by the

DIRECTOR OF CENTRAL INTELLIGENCE

The following intelligence organizations participated in the preparation of this estimate: The Central Intelligence Agency and the intelligence organizations of the Departments of State, the Army, the Navy, the Air Force, The Joint Staff, and the Atomic Energy Commission.

Concurred in by the

INTELLIGENCE ADVISORY COMMITTEE

on 7 May 1957. Concurring were the Special Assistant, Intelligence, Department of State; the Assistant Chief of Staff, Intelligence, Department of the Army; the Director of Naval Intelligence; the Director of Intelligence, USAF; the Deputy Director for Intelligence, The Joint Staff; and the Atomic Energy Commission Representative to the IAC. The Assistant Director, Federal Bureau of Investigation, abstained, the subject being outside of the jurisdiction of his Agency. See appropriate footnotes, however, for the dissenting views of the Director of Naval Intelligence.

~~TOP SECRET~~

Copy No. 173

CENTRAL INTELLIGENCE AGENCY

DISSEMINATION NOTICE

1. This estimate was disseminated by the Central Intelligence Agency. This copy is for the information and use of the recipient indicated on the front cover and of persons under his jurisdiction on a need to know basis. Additional essential dissemination may be authorized by the following officials within their respective departments:

   a. Special Assistant to the Secretary for Intelligence, for the Department of State
   b. Assistant Chief of Staff, Intelligence, for the Department of the Army
   c. Director of Naval Intelligence, for the Department of the Navy
   d. Director of Intelligence, USAF, for the Department of the Air Force
   e. Deputy Director for Intelligence, Joint Staff, for the Joint Staff
   f. Director of Intelligence, AEC, for the Atomic Energy Commission
   g. Assistant Director, FBI, for the Federal Bureau of Investigation
   h. Assistant Director for Central Reference, CIA, for any other Department or Agency

2. This copy may be retained, or destroyed by burning in accordance with applicable security regulations, or returned to the Central Intelligence Agency by arrangement with the Office of Central Reference, CIA.

3. When an estimate is disseminated overseas, the overseas recipients may retain it for a period not in excess of one year. At the end of this period, the estimate should either be destroyed, returned to the forwarding agency, or permission should be re-requested of the forwarding agency to retain it in accordance with IAC-D-69/2, 22 June 1953.

4. The title of this estimate when used separately from the text, should be classified:
~~CONFIDENTIAL.~~

DISTRIBUTION:
White House
National Security Council
Department of Defense
Department of State
Operations Coordinating Board
Atomic Energy Commission
Federal Bureau of Investigation

NATIONAL INTELLIGENCE ESTIMATE

JOINT ATOMIC ENERGY INTELLIGENCE COMMITTEE

THE SOVIET ATOMIC ENERGY PROGRAM

NIE 11-2-57

7 May 1957

This estimate supersedes NIE 11–2–56, 8 June 1956, and Annex D to NIE 11–5–57, 12 March 1957.

This estimate was prepared and agreed upon by the Joint Atomic Energy Intelligence Committee, with footnotes by the Navy member, which is composed of representatives of the Departments of State, Army, Navy, Air Force, the Atomic Energy Commission, the Joint Staff and the Central Intelligence Agency. The FBI abstained, the subject being outside of its jurisdiction.

A group of expert consultants working with the Joint Atomic Energy Intelligence Committee have reviewed this estimate and generally concur with it. The estimate, with footnotes, was approved by the Intelligence Advisory Committee on 7 May 1957.

TABLE OF CONTENTS

TABLE OF ILLUSTRATIONS

NATIONAL INTELLIGENCE ESTIMATE 11-2-57

THE SOVIET ATOMIC ENERGY PROGRAM[1]

THE PROBLEM

To estimate the current status and future course of the Soviet atomic energy program to mid-1967 on the basis of information available from all sources.

This estimate *does not* take into consideration the impact that any form of nuclear test moratorium or limitation on nuclear weapons production would have on the Soviet atomic energy program.

[1] This report constitutes Part I of the over-all estimate. Part II, dealing with the possible allocation of nuclear materials to various military uses, is under preparation.

THE SOVIET ATOMIC ENERGY PROGRAM[2]

SUMMARY AND CONCLUSIONS

A. *Trend Of The Soviet Atomic Energy Program.* There is substantial evidence that the USSR is continuing to expand steadily both its military atomic energy activities and its program for the non-military uses of atomic energy. (See Figure I for geographical locations.)

1. A total of sixteen nuclear tests have been detected since January 1956, including four thermonuclear tests with yields between one-half (½) and three (3) megatons. This is in contrast with a total of nineteen tests detected during the period 1949–1955. (Par. 80–86)

2. Efforts are being made by the USSR to increase its uranium ore and uranium metal supply which is already capable of supporting a very substantial atomic energy effort. Although we estimate a substantial Soviet program for the expansion of fissionable material production, the availability of such materials will continue throughout the period of this estimate to be a limiting factor in determining the size of many military and non-military programs. (Par. 40–41 and 46–47)

3. Although a substantial nuclear power program is still envisioned by the USSR, its initially announced goals have apparently been reduced during recent months toward more realistic objectives. In general, non-military applications are being fostered on a broad base both within the USSR and in international programs that reach all countries within the Soviet Bloc and that endeavor to compete with the West in the courtship of all significant neutral powers. (Par. 35–38a and 106–114)

4. The USSR has a broad scientific base in the nuclear sciences and is competent to continue making important progress not only in areas of fundamental research, but also in improving nuclear weapons and integrated weapon systems. In experimental nuclear physics, Soviet capability, now estimated to be second only to that of the US, will continue to improve. (Par. 10–25)

5. We estimate the Soviet atomic energy program will continue to enjoy the very high priority that has been accorded to it in the past.

B. *Raw Materials.* We estimate that approximately 8,000 metric tons of uranium (in terms of recoverable metal) were mined during 1956 in the USSR and its satellites, of which approximately 4,600 metric tons were obtained in East Germany. This total quantity is more than adequate to support current fissionable materials output as calculated in this estimate. Substantial uranium ore reserves exist within the Soviet Bloc and particularly the USSR, and the exploita-

[2] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

tion of these resources, as well as of other raw materials essential to atomic energy activities, is being steadily expanded. (Par. 40–42)

C. *Plutonium Production.*[3] 1. In the past our estimates of the production of plutonium have been based on the [redacted] The Soviets appear to have been accumulating raw materials in quantities too great to be accounted for by a stable annual plutonium production rate, even when the demands of an expanding uranium-235 program and of a reasonable reserve program are considered. There is also direct information which suggests continued expansion of Soviet production reactor capacity. The Soviets have, moreover, employed plutonium liberally in their weapon tests. In the light of this evidence, we estimate that the Soviets have probably been [redacted] (Par. 68–70 and Table XIII)

2. Our estimate of probable current and future Soviet plutonium production is based upon estimated Soviet uranium ore procurement, assumed stockpiling practices, estimated heavy-water production, estimated site construction time schedules, deductions and assumptions on Soviet production reactor designs, and [redacted] Starting in 1959, we assume that all new plutonium production capacity will come from the power reactor program. Our present and future estimates of cumulative and annual plutonium production are given [redacted] (Par. 64–76)

D. *Uranium-235 Production.*[3] Our estimates of Soviet production of U–235 (as shown in Figure IV) prior to mid-1953 are

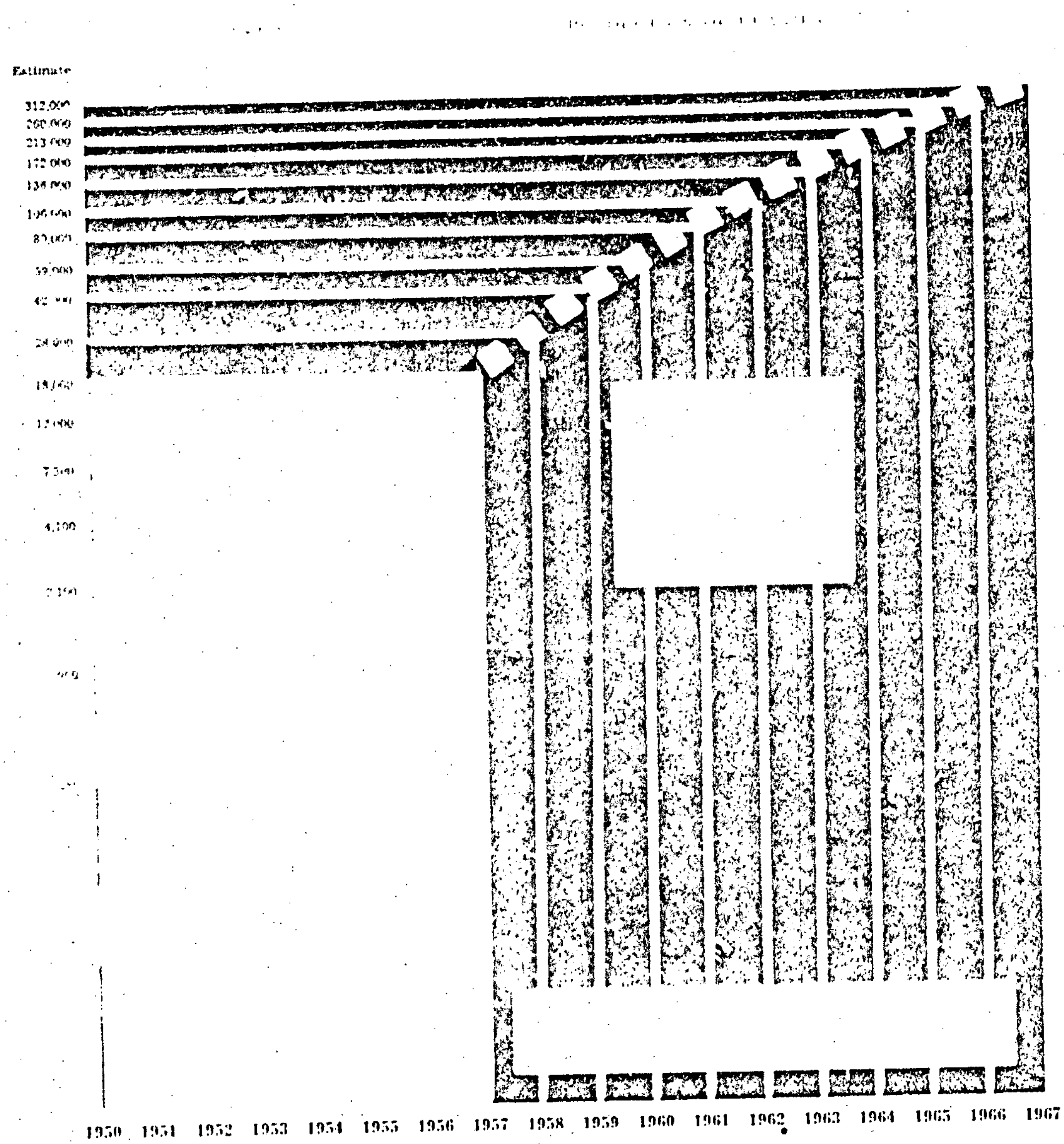
---

The Director of Naval Intelligence does not concur in the figures contained herein for the estimated production of U-235. He does not believe that more than 300 kg of weapon grade U-235 were available in 1953. He does not believe that intelligence available as to barrier improvements, utilization of electricity, and assumptions made justify the increased production set forth. He believes, if present methods, utilizing improved techniques, for production of U 235 are continued, a cumulative stockpile by mid-1957 will be near 5,000 kg, near 15,000 kg by mid-1961 and near 40,000 kg by mid-1967. These values are consistent with the limited use of U-235 in the weapon test program and in balance with the plutonium estimate [redacted] However, if new methods of production were instituted which could be effective by 1961 the quantities could be radically increased after that date.

The Director of Naval Intelligence does not concur in the estimate of production of plutonium after 1953. [redacted] Accordingly, he believes that the estimated cumulative production of plutonium would be 3,200 kg through mid-1957 and, by extrapolation, 7,000 kg through mid-1961 and 16,000 kg through mid-1967.

The Director of Naval Intelligence believes that the plutonium produced in the Soviet nuclear electric power reactor program might be utilized as fuel in that program, leaving insignificant amounts available for their weapons stockpile. This is consistent with Soviet statements concerning the power program and with available intelligence.

FIGURE IV


Estimate
312,000
213,000
172,000
138,000
1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967

based on quantities of barrier procured through 1952 for their gaseous diffusion plants, as well as information from returned German scientists on barrier fabrication methods and barrier quality, and allows for moderate Soviet improvement in plant design and compressor efficiency as indicated by these sources. This evidence of increased Soviet capability has been extrapolated into the post-1953 period as an assumed gradual improvement in the efficiency in utilization of electric power. The production of U-235 from mid-1953 to mid-1967 has been obtained by applying estimated plant efficiency in terms of utilization of electric power to the average electric power estimated to be available for isotope separation. (Par. 52–62)

E. *Nuclear Weapons Progress.* 1. Commencing with the first Soviet nuclear test conducted in August 1949, a total of 35 tests have been detected in which plutonium, uranium-235, and in one instance uranium-233 have been used as the fissionable materials. There is evidence that the USSR is making a concerted effort to perfect a variety of improved nuclear weapons, particularly those employing thermonuclear principles. Test activities in 1956 extended throughout the entire year, from 2 February until 14 December, and included nine detonations. [redacted] In addition, seven tests have been conducted during the first four months of 1957. Altogether, five thermonuclear tests with yields of from one-half up to about three megatons have been carried out; however, a possible interpretation of the data is that the high-yield weapons detonated at the Semipalatinsk proving ground were deliberately reduced yield versions of more powerful and efficient weapons. (Par. 80–86)

2. It is significant that: [redacted] (b) There has been evidence during the past 18 months of development and testing of nuclear warheads in guided missiles. (Par. 86–97)

3. [redacted] In general, we anticipate that the USSR will be capable of producing improved nuclear weapons of the range of yields and characteristics required to support its military requirements. [redacted]

[redacted]

(Par. 87–98)

F. *Nuclear Electric Power Program.* 1. The Soviets are engaged in a comprehensive reactor development program which will permit them to keep generally abreast of world progress in this field. They have had one small prototype power reactor with a capacity of five electrical megawatts (EMW), in operation since June 1954, which although inefficient, has permitted useful experimental studies in power reactor operation. (Par. 35–38a)

2. Recent information indicates the USSR has revised the time scale and reduced its ambitious nuclear power goal from 2,000 2,500 megawatts to 1,400 megawatts of electrical power under its Sixth Five-Year Plan (1956–1960). (See Table III.) This reduced plan is still quite substantial, but is within Soviet capability with a high priority effort. The USSR emphasizes that this program is oriented toward making future nuclear power economically competitive with conventional power costs. The Soviets state that some of the plutonium produced could conceivably be recycled in their reactors but we estimate that this plutonium will be allocated by the USSR to weapons stockpiles.[7] Beginning in 1959, the nuclear power program will consume significant quantities of U-235. However, we do not believe this loss of fissionable material to the Soviet weapons program will exceed approximately 5 per cent of the total U-235 available to the USSR at any time during the period mid-1959–mid-1967. (See Figure IV) (Par. 35–38a)

G. *Nuclear Propulsion Capabilities.* 1. We believe that a nuclear propulsion reactor suitable for naval and marine applications is currently under construction. We estimate that: (a) a nuclear propulsion reactor for a surface ship (icebreaker) will be installed in early 1958 and that the ship will undergo operational tests in late 1958 or early 1959; (b) a nuclear propulsion reactor for a submarine could be available for installation in 1957; and (c) that by the time these ships complete operational tests, the Soviets could undertake the construction of a variety of surface ships and submarines. (Par. 104–105)

2. There is no evidence of Soviet activities directly identified to nuclear propulsion for aircraft or guided missiles. However, frequent references to the feasibility of aircraft nuclear propulsion have been made during the past year, both in newspapers and magazines and statements by some of the highest officials in the USSR. We estimate that: (a) the Soviet aircraft nuclear propulsion reactor program is probably now engaged in development and testing of reactor components and sub-systems; and, (b) a reactor system suitable for nuclear propulsion of subsonic aircraft could probably be available to the Soviets in 1962; (c) the USSR has, at most conducted basic research on developmental components for a missile propulsion reactor system. (Par. 102–103)

See footnote 3, page 2, for the position of the Director of Naval Intelligence.

H. *International Activities.* The USSR has continued its role as an active participant in international atomic energy activities including scientific conferences and the negotiations to establish an International Atomic Energy Agency. The Joint Nuclear Research Institute, located at Dubna near Moscow, was created in 1956 to serve as the focal point of Sino-Soviet Bloc technical cooperation. Arrangements for furnishing swimming pool type research reactors, particle accelerators, radioisotopes and technical training of personnel to Bloc countries are continuing and delivery of the actual reactors is scheduled for 1957. In addition, plans have been announced for construction of power reactors with Soviet assistance in Czechoslovakia, East Germany, Hungary and Rumania. Aid agreements have been reached with Yugoslavia and Egypt, similar to those with Bloc countries, although difficulties have arisen in implementation of the Yugoslavian agreement. We estimate that the USSR will continue to make offers of technical aid as well as assistance in the construction of power stations both within the Bloc and possibly to non-Bloc countries, and that the USSR has the capability of fulfilling such commitments. The Soviets allege that they will impose no restriction on the use or disposition of nuclear materials in their aid program. (Par. 106–114)

DISCUSSION

I. INTRODUCTION

1. While the exact extent of Soviet capability in the atomic field remains uncertain, the general nature and some of the details of the Soviet atomic energy program can be assessed with fair reliability. Available evidence establishes the existence in the USSR of: (a) a high priority, extensive atomic energy program, primarily directed toward military application, which is continuing to expand; (b) an ample uranium ore base on which to carry out this program; (c) a substantial stockpile of fissionable materials; (d) a proven capability for the establishment of nuclear-electric power stations; (e) a capability, so far believed to be unrealized, of utilizing nuclear power for propulsive purposes; (f) and a proven capability of producing explosions in yield ranges from a few kilotons up to several megatons and of employing both fission and fusion principles.

2. Reliable evidence indicates that Soviet military planning includes the employment of nuclear weapons for offensive air operations, in support of ground and naval operations, and possibly air defense. At least twice since 1953 there has been military participation in the Soviet nuclear weapons test program indicative of both weapons effects tests and military maneuvers.

3. Our knowledge of the status of the Soviet atomic energy program as of the end of 1956 is derived from a considerable volume of evidence. Evidence received since our last estimate on the Soviet atomic energy program (NIE 11-2-56, 8 June 1956) primarily concerns the mining of uranium ore, its transformation into uranium metal, the production of plutonium, research on reactors and isotope separation methods, the first Soviet gaseous diffusion uranium-235 separation plant, electric power available to gaseous diffusion plants, further testing of weapons, and military training and indoctrination in atomic warfare.

II. HISTORY AND ORGANIZATION

4. The Soviet atomic energy program started in August 1940 with the formation of a Commission on the Uranium Problem attached to the Presidium of the Academy of Sciences, USSR. Members of this commission were representatives from various laboratories expected to be major contributors on the problem. Beginning in late 1943, the Ninth Directorate of the People's Commissariat of Internal Affairs (NKVD) was organized to make concurrently preliminary studies in nuclear physics with special attention to atomic energy. In 1944 it became responsible for uranium mining in the USSR, and, beginning in May 1945, it recruited more than 200 German and Austrian scientists to work in the USSR on atomic energy problems at several laboratories subsequently built for this purpose.

5. In November 1945 a First Chief Directorate was created and attached to the Council of Ministers, and was given the responsibility for the expansion of the entire Soviet atomic energy program. L. P. Beriya was the responsible member of the Council of Ministers and thus exercised over-all direction of policy and drew into the program the best talent and leadership of the nation. These leaders, for the most part, retained their old positions along with their new responsibilities. By appointing to the program representatives of many diverse organizations such as the Ministry of Internal Affairs, the Ministry of the Chemical Industry and many others, assurance of the high priority necessary to implement the program was attained. Between 1945 and 1950 the First Chief Directorate gradually took over the responsibilities of the Ninth Directorate of the NKVD until in early 1950 the Ninth Directorate relinquished the last of its functions, control of the German scientists, and was dissolved.

6. The growth of the Soviet atomic energy effort necessitated its major reorganization in early 1950. At this time a Second Chief Directorate was formed and also attached to the Council of Ministers. The First Chief Directorate relinquished to the Second Chief Directorate control of mining, to include the development of new uranium deposits, the concentration and refining of uranium both inside and outside of the USSR. This freed the First Chief Directorate to concentrate on the production of fissionable materials and the manufacture of weapons. Supply, personnel and other services common to both directorates were apparently placed in a body serving both directorates, thus another chief directorate was possibly formed.

7. This organizational structure apparently continued until the arrest of Beriya in June 1953. At that time, the Ministry of Medium Machine Building was organized with V. A. Malyshev as the minister and this new ministry gradually took over the functions of the Chief Directorates, except for Satellite mining operations. This latter activity was made subordinate to the Chief Directorate of Soviet Property Abroad, Ministry of Foreign Trade, and it is probably still under the Ministry of Foreign Trade for administration but is clearly subordinate to the Ministry of Medium Machine Building for operational matters. Late in 1953 Malyshev was appointed a Deputy Chairman of the Council of Ministers. However, in February 1955, Colonel General A. P. Zavenyagin, a prominent and leading figure in the program from its beginning, was appointed Minister of Medium Machine Building and elevated to the position of Deputy Chairman of the Council of Ministers. Thus, he replaced Malyshev as over-all policy director and manager of day-to-day operations of the entire Soviet atomic energy program. In December 1956, Zavenyagin died and his successor, appointed on 2 May 1957, is Mikhail G. Pervukhin, who has been associated with the atomic energy program since its beginning and was most recently the Chairman of the State Economic Commission for Short Term Planning.

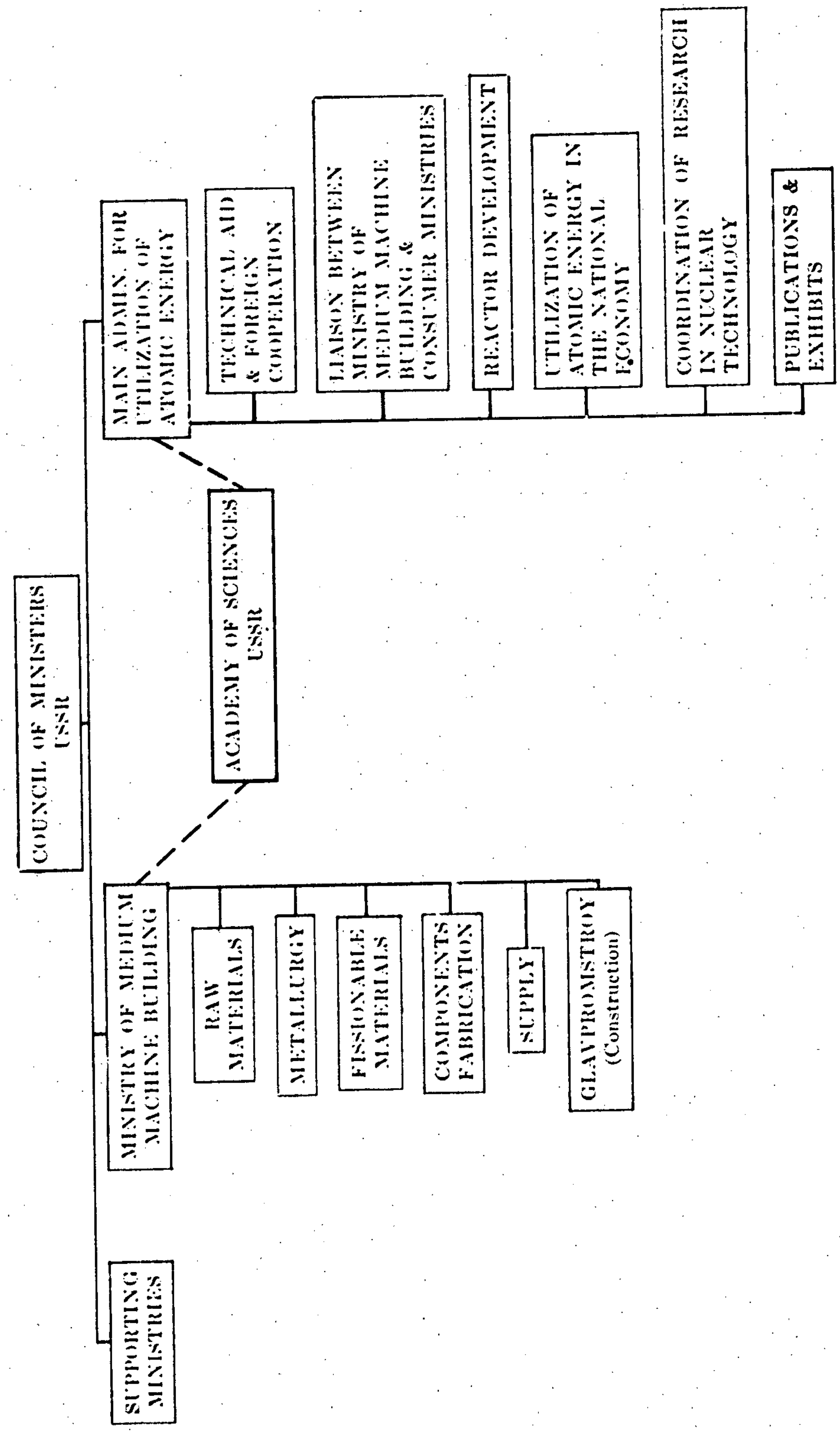
8. In April 1956, TASS announced the formation of a new atomic energy coordinating body, the Main Administration for the Use of Atomic Energy attached to the Council of Ministers. Yefrim P. Slavskiy is head of this new Administration. The Main Administration

was created to fulfill several functions: to develop cooperation between the USSR and other countries in the non-military uses of atomic energy; to make extensive use of atomic energy in the national economy in cooperation with the industrial ministries and to resolve problems connected with this application; to design reactors for power stations and to develop atom powered engines for use in transportation; to build and operate experimental reactors; to coordinate research in nuclear technology, e.g., the production and use of radioisotopes and the effect of radiation on metals; to supply laboratories with experimental equipment such as counters, reactors, and accelerators. The Main Administration is also responsible for the publication of scientific and technical works on utilization of atomic energy and for holding exhibits on peaceful uses of atomic energy both in the Soviet Union and in other countries.

9. It appears, then, that there is a clear-cut division of responsibilities between the Ministry of Medium Machine Building and the Main Administration for Use of Atomic Energy. (See Table I.) The Ministry continues with its former functions for all production aspects of the atomic energy program, while the Main Administration supervises the application of peaceful uses of atomic energy within the USSR and the cooperation of the the USSR with other countries in these matters. The Academy of Sciences is apparently used to advise and conduct supporting research for both the Ministry of Medium Machine Building and the Main Administration.

TABLE I

PROGRAM ORGANIZATION



III. SOVIET TECHNICAL CAPABILITIES IN NUCLEAR ENERGY

10. Science and technology continue to be predominately encouraged by the Soviet government and emphasized in their educational system. Scientists are a privileged group held in high esteem. Soviet research personnel are concentrated in support of heavy industry and military development fields.

11. Soviet manpower and capability in basic scientific fields necessary for support of a comprehensive nuclear energy program are impressive and competent. Within the nuclear energy field we find a broad scientific base which is competent to continue to make important progress not only in fundamental fields but a capability for developing better nuclear weapons and applications to integrated weapons systems.

12. *Nuclear Physics.* We estimate the present capability of the USSR in experimental nuclear physics to be second only to that of the US. The construction of high-energy particle accelerators such as their 680 million electron-volt (MEV) synchrocyclotron and the 10 billion electron-volt (BEV) proton synchroton have been the most impressive Soviet accomplishments in nuclear physics. However, these accelerators are merely impressive in size since they are essentially scaled-up versions of US accelerators. Research work reported using the 680 MEV machine has been competent but uninspired. Construction of the 10 BEV machine was completed in 1956, and it became operational in 1957.

13. During 1956, the Soviets revealed several highly original ideas for particle accelerator designs which have not been incorporated in operating accelerators. Some of these may have stemmed directly from Soviet research effort on controlled thermonuclear reactions. It appears that there is effective exchange of ideas between the accelerator and thermonuclear groups.

14. *Controlled Thermonuclear Research.* Soviet research in the application of controlled thermonuclear reactions for the production of power was first revealed in July 1955 at the Conference of the Academy of Sciences on Peaceful Uses of Atomic Energy. Subsequent reports describing parts of the Soviet effort reveal that the USSR has the technical competence required to support an effective research program in this field. The experimental work is quite creditable and indicates an appreciable effort and manpower expenditure. The Soviets have stated that while they have not attained usable energy from controlled thermonuclear reactions, this research is continuing. We estimate that the USSR will not produce usable power from thermonuclear processes for many years.

15. *Instrumentation.* The USSR is apparently developing and producing the instruments required to support their nuclear energy program. Instruments viewed at international conferences and trade fairs, although mostly auxiliary instruments, appear to be well designed and gave evidence of quality workmanship. Several Satellite nations are producing various instruments to Soviet specifications that are being delivered to the USSR in quantity for use in nuclear energy and other programs.

16. The capabilities of Soviet nuclear physicists for developing integrated instrumentation equipment for nuclear research are considered adequate for support of the Soviet nuclear energy program. It appears that the USSR lags the US somewhat in the development of such equipment as nuclear resonators, neutron time-of-flight spectrometers, coincidence counters and scintillation counters. However, the Soviets have developed an excellent photomultiplier tube, which is an essential component for scintillation counters. Also, the Soviet mass spectrometer, MS-4, appears to have good versatility and to be a modern, well engineered instrument.

17. *Computers.* The USSR has demonstrated a considerable technical competence for the development of high-speed digital computers. Such computers play an important role in the solution of many problems in nuclear physics and the design of nuclear weapons. The BESM and M-2 computers, designed and constructed by the Soviet Academy of Sciences,

were put into operation in 1952 and were comparable to the best computers available in the US at that time. The Soviets are currently building a computer which will have an operating speed almost as fast as the US IBM 704, one of the best in the US. Apparently, the BESM and the M-2 were the only high-speed computers in the USSR until 1955. Two other computers, the STRELA and the URAL, designed by the Ministry of Instrument Building and Means of Automation were scheduled to go into serial production in 1955. However, as of mid-1956 the Soviets had produced less than ten STRELA's and still had not delivered a URAL computer promised to India by the end of 1955.

18. A weakness in the Soviet computer program is found in its extent rather than in its quality. We believe that the Soviet failure to produce large numbers of high-speed digital computers is probably due to the Academy of Sciences not making its experience in computer development and construction immediately available to the industrial ministry responsible for mass production of these machines. The development of a new Soviet computer which resembles the US IBM 704 is the first evidence of adequate collaboration between the Academy of Sciences and the Ministry of Instrument Building and Means of Automation. While the Soviets will probably produce enough STRELA and URAL computers to satisfy their immediate needs, large scale production of high-speed computers probably will not be undertaken until a standardized model of the new computer is available.

19. *Chemistry.* The Soviets have revealed through papers presented at international conferences and open literature publications a high degree of technical competence in various fields of chemistry. The only accomplishments directly related to their atomic energy program, revealed to the West, have been in the uses and applications of radioisotopes with apparent emphasis on tracers in chemical reactions and control mechanisms. The fundamental aspects of isotope separations and materials concentration for the Soviet nuclear program have been notably omitted from publication and discussions. Soviet research in nuclear chemistry will keep up with world progress and has the capability to adequately support the Soviet nuclear weapons program.

20. *Metallurgy.* The USSR has placed added emphasis on metals in its Sixth Five-Year Plan. In particular, production of lithium, beryllium, zirconium, nickel, and other metals essential to the atomic energy program is to be increased many fold. Special efforts are to be made to increase the purity of metals possessing useful nuclear properties. Basic research for this phase of the program has already been initiated and papers have been published on the application of the iodide method for producing extremely pure chromium and zirconium. Mention is also made of the separation of hafnium from zirconium and other methods for separation of impurities. This work strongly suggests suitability of these metals to nuclear applications. The continued interest of the Soviet Union in molten salts systems containing such elements as lithium, beryllium and thorium further evidences a broad base of research possibility for reactor purposes.

21. Soviet fundamental metallurgical research scientists display outstanding ability and have produced some original concepts during the last year. We estimate that the Soviet capabilities in metallurgical research will continue to support adequately the Soviet atomic energy program.

22. *Medicine and Biology.* Soviet research activity in the bio-medical sciences increased to a high pitch during 1955–56. This work is largely radiobiological in substance but could provide improved therapy for mass atomic casualties as well as health physics criteria for peaceful utilization of nuclear energy.

23. Bio-medical research concerned with the nuclear energy program of the USSR is undergoing a large-scale enlargement and consolidation. This is evident by the recent appearance of journals dealing almost exclusively with bio-medical aspects of nuclear energy and the scheduled early completion of several

major research centers. This research has become an integral part of the Five-Year Plans of the Academy of Sciences.

24. A shift in research emphasis has been indicated in the health physics field by some excellent work on toxicology of certain metals connected with the nuclear energy program and biological effects of ionizing radiations and radioactive aerosols. We estimate that the Soviets will keep pace with world progress in such fields as prophylaxis, therapy of radiation syndrome, and biochemical, hematological, immunological and systemic effects.

25. Soviet health physics standards discussed at the Geneva Conference and stated in military doctrine are more restrictive than those of the Western World. Cases are known in which these were not rigorously adhered to.

IV. SOVIET REACTOR DEVELOPMENT

26. *Nuclear Reactor Technology.* The USSR has a comprehensive reactor program and has demonstrated excellent capabilities in reactor technology. Scientific intelligence techniques prove that the Soviets have operated reactors for plutonium production since 1948. The first Soviet full-scale production reactor was apparently developed directly from a crude, low-power graphite reactor experiment.

27. Soviet research on reactors has encompassed both well known types and some of original design. This program includes studies on nuclear fuels, moderators, coolants, fuel elements and structural materials. Soviet physicists and engineers connected with their research reactor program possess a high degree of technical competence. They have demonstrated that they do not necessarily follow Western practices and are competent to take independent approaches, as illustrated by the original design of the fuel elements for the existing Atomic Power Station reactor. Published Soviet research on advanced coolants, such as liquid metals and molten salts, as well as research on high-temperature moderator materials reveals the existence of an adequate experimental base for development of advanced nuclear reactors.

28. The experience gained by the Soviets from production reactors, research reactors, and their extensive experimental program provides a potential in advanced reactor technology adequate for continued support of the ambitious power reactor development program which is part of the Soviet Sixth Five-Year Plan.

29. *Nuclear Reactor Development History.* Evidence indicates that the design and construction of the Reactor Physical-Technical in 1950–52 marked the advent of the Soviet developmental power program. (See Table II.) This reactor, completed in 1952, gave the Soviets the capability of testing, under actual reactor conditions, proposed fuel elements, cooling systems, and structural materials necessary for the development of new reactors. In addition, the Reactor Physical-Technical acted as the prototype for the first 5 EMW* power reactor (critical May 1954) which has provided the Soviets with experience in nuclear power plant operation. The Soviets have stated that they are constructing a large 200 EMW graphite-moderated, water-cooled power reactor which will be an expanded version of the 5 EMW power reactor.

30. A reactor with ordinary water as the moderator was first designed in 1951 and constructed several years later. This first 300 kilowatt swimming pool type reactor together with a later 2,000 kilowatt version completed in 1955–1956 has provided the Soviets with facilities to determine valuable data required for the development of the large pressurized water reactor. This type of reactor is also used for the testing of new shielding materials and configurations.

31. Following the plutonium criticality experiments in 1953, the Soviets constructed a 200 kilowatt plutonium fast reactor, critical in 1956, which is cooled with mercury. An expanded 5,000 kilowatt version is scheduled for operation in 1957 and will provide operational experience with sodium cooling. These re-

* EMW (Electrical Megawatt) is used to designate the electrical power. All other power units and abbreviations designate thermal or heat power.

actors will provide the facilities to obtain data necessary for the development of a fast plutonium breeder reactor. The Soviets have announced that two power reactor pilot plants will utilize sodium as the coolant. One will be a plutonium fast breeder and the other will be sodium-cooled and graphite-moderated.

32. The 500 kilowatt heavy-water research reactor, placed in operation in 1949, enabled the Soviets to obtain experience necessary for the construction of heavy-water moderated production type reactors. This research reactor appears to have been modified sometime in 1953–1954 to permit the Soviets to conduct feasibility studies on gas cooling of heavy-water moderated reactors. The heavy-water reactor has been modified to operate at a higher power of about 2,000 kilowatts, and this reactor will undoubtedly be used in the development of any gas-cooled, heavy-water moderated power reactor and in the homogeneous thorium breeder. The homogeneous thorium reactor will use a heavy-water slurry of uranium oxide as the fuel.

33. Feasibility studies on boiling-water reactors and measurements of the thermal conductivity of gaseous films in boiling water were conducted in 1955. This research was augmented by information obtained by the USSR at the 1955 Geneva Conference in Peaceful Applications of Atomic Energy, and provided background necessary to the construction of the proposed boiling-water reactor.

34. The beryllium and beryllium oxide moderated reactor which went critical in August 1954 has undoubtedly enabled the Soviets to determine the feasibility of using this moderator in future reactor developments. While we have no knowledge of Soviet plans to use this moderator, it is possible that they may decide to use beryllium and beryllium oxide in future power and propulsion reactors due to the high temperature characteristics of this material, if they can foresee a solution to the thermo-mechanical problems involved.

TABLE II

SIGNIFICANT SOVIET RESEARCH AND PROTOTYPE REACTORS

Research Reactors	Location	Thermal Power Kilowatts	Fuel	Moderator	Coolant	Affiliation	Date of Criticality	Remarks
Fursov Graphite	Moscow	10	Nat. Uranium ~45 tons	Graphite	None	(LIPAN) Laboratory of Measuring Instruments	1947	First reactor in USSR.
Heavy Water No. 1	Moscow	500	Nat. Uranium, 2100 Kg.	Heavy Water 4.5 tons	Heavy Water	Thermo-technical Laboratory	April 1949	Believed to have been modified in 1954 for gas cooling experiments.
Reactor Physical Technical	Moscow	10,000	10% enriched uranium ~1200 Kg	Graphite	Water	LIPAN	April 1952	Full power in December '52. Testing materials, fuel elements and coolant systems designed Sep. '50
Swimming Pool No. 1	Moscow	300	10% enriched uranium 35 Kg	Light Water	Water	LIPAN	~1953	Testing of shielding materials and configurations.
First Power	Obninskoye	30,000 5 EMW	5% enriched uranium 550 Kg	Graphite	Water	Atomic Research Institute	June 27, 1954	Experimental power plant.
Physical Beryllium	Obninskoye	10	10% enriched U_3O_8 Powder 78 Kg	Beryllium metal and oxide	None	Atomic Research Institute	August 1954	Designed 1953. Contained a Po-Be neutron source.
Swimming Pool No. 2	Moscow	2,000	10% enriched uranium 45 Kg	Light Water	Water	Moscow State Univ.	~1955	13 Test loops. Basic neutron research.
Plutonium Fast	Obninskoye	200	Plutonium 12 Kg	None	Mercury	Atomic Research Institute	February 1956	First Metal Cooled Reactor
Heavy Water No. 2	Moscow	2,000	2% enriched uranium	Heavy Water	Heavy Water	Thermo-technical Laboratory	1956-57	Modification of Heavy Water No. 1 to obtain a higher power and flux.
Sodium cooled fast	Obninskoye	5,000	Plutonium 50 Kg	None	Sodium	Atomic Research Institute	1957	First sodium cooled reactor.
Icebreaker	Leningrad	200,000 (44,000 HP)	Enriched Uranium	Unknown	Water	Min Shipbuilding Industry	1958	Probably be pressurized water type.

V. SOVIET NUCLEAR POWER REACTOR PROGRAM

35. The nuclear power program of the Sixth Five-Year Plan adopted in 1956 included a reactor generating capacity of 2,000 to 2,500 electrical megawatts (EMW) to be in operation by the end of 1960. Further information indicates that a total of 25,000 EMW was being considered as the goal over the next twenty-five years. This program, if achieved, would have a major impact on future fissionable material stockpiles both as a consumer of uranium-235 and as a producer of plutonium. During the period 1958 to 1960, these stations will provide experience in nuclear engineering, mass production of fuel elements, and fuel processing. This plan, as repeatedly stated by high ranking Soviet scientific personnel, was to construct seven different types of experimental power reactors in the period 1956–1960. Three of these reactor types were to be incorporated in four, or possibly five, power stations. All were to be full-scale prototypes. Four experimental reactors of a small capacity, which have been described and scheduled for construction, will round out the Soviet reactor development program.

36. We believe that this original program, calling for approximately 2,500 EMW of nuclear power capacity by 1960, is very ambitious and probably could not be achieved during this time period even with a very high priority effort. It calls for a large capital outlay, a concerted construction program, and concurrent solution of a number of difficult reactor engineering problems.

37. There is a good indication that the USSR now fully realizes the difficulties involved in carrying out the original program and plans to reduce their 1960 goal from 2,500 EMW to 1,400 EMW. This reduced Soviet Five-Year Plan for nuclear power still is substantial, but one which is much more attainable.

38. In connection with the release of information on their reduced program, the Soviets have stressed that it is oriented toward producing future nuclear power that is economically competitive with the conventional power costs in the Urals and European USSR. However, an analysis of information on the characteristics of the large-scale prototype reactors involved indicates they are designed to produce significant amounts of plutonium, i.e., quantities equal to the amount of 90% equivalent U-235 consumed in the reactors. The Soviets further state that this plutonium could conceivably be recycled as subsequent charges in the reactors. However, relative to U-235, plutonium has an even greater value in a weapons program than in a power reactor program. Therefore, we believe this plutonium will be allocated by the USSR to weapons stockpiles.[a]

38a. The original Soviet plans for nuclear power include the construction of power stations near Moscow, Leningrad, Voronezh, and in the Urals. There is no firm information as to which specific reactor is to be installed at any of the locations except Moscow. These plans included the construction of the following types of power reactors:

a. Two 210 EMW pressurized water reactors apparently have been designated for the first station to be placed in operation near Moscow in late 1958. (See Table III.) The seed-core enrichment concept is planned to be used in this type of reactor with the fuel loading consisting of about 73 kilograms of 90% enriched UO_2 and 23 metric tons of natural UO_2. It is planned that these reactors will be of the pressure vessel type and will use stainless steel clad fuel elements. However, whether the reactors in the third station (see Table III) will utilize zirconium cladding or not will depend on the success the Soviets have in developing suitable production techniques. We estimate that the third station will employ this type of reactor and will become operational at the end of 1959.

b. The second station will employ 200 EMW graphite-moderated and water-cooled reactors which stem directly from the 5 MW station at

[a] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

Obninskoye and is expected to operate on 1.2% enriched uranium with a thermal-to-electrical net efficiency of 34.7%.

c. Recent evidence indicates that the 200 EMW heavy-water moderated gas-cooled type reactor included in the original Sixth Five-Year Plan has been omitted from the revised plan. This reactor was to have operated on natural uranium as the fuel with a thermal-to-electrical efficiency of 28% and would have required 80 metric tons of heavy water. It is not known whether the plans for this reactor have been merely deferred or dropped altogether.

d. Four experimental (pilot plant type) reactors of 5 – 70 EMW each are also included in the revised plan. These reactors are stated to be of the following types: a plutonium fast reactor; a homogeneous thorium-breeder reactor; a boiling-water reactor; and a sodium-cooled, graphite-moderated reactor. It is not known whether or not these reactors will be used, as originally planned, to form a composite experimental atomic power station.

TABLE III

ESTIMATED TIME SCHEDULE OF THE SOVIET NUCLEAR POWER PROGRAM

Power Stations	Type Reactor	Reported Heat to Electricity Efficiency Percent	Area of Probable Location	Initial Date of Operation 1958 Mid	1958 End	1959 Mid	1959 End	1960 Mid	1960 End	Total EMW
1.	Water-Moderated Water-Cooled	27.6%	Moscow		210		210			420
2.	Graphite-Moderated Water-Cooled	31.7%	Urals			200		200		400
3.	Water-Moderated Water-Cooled	27.6%	Leningrad				[10] 210		[10] 210	420
4.	D_2O Moderated Gas-Cooled	Unknown, although included in original plan, now presumed to be dropped or deferred.								
5.	Unknown	Unknown, although included in original plan, now presumed to be dropped or deferred.								
Experimental [11]	Boiling Water								35	
	Plutonium Fast Breeder			5						160
	Homogeneous Thorium Breeder							50		
	Graphite-Moderated Na-Cooled						70			
								Total EMW		1,400

[10] Pressure vessel type with zirconium clad fuel elements.

[11] The Soviets have stated these reactors would be in the range of 5-70 EMW. The values for the specific reactors have been assumed.

VI. PRODUCTION OF FISSIONABLE MATERIALS

40. *Uranium Mining.* Much quantitative information is available on mining and ore enrichment in East Germany. Some quantitative information is available on the other Satellites, notably Czechoslovakia, Rumania and Bulgaria, but information on the USSR is limited to knowledge that mining is taking place in a number of areas. (See Figure 1.) We estimate that approximately 8,000 metric tons of uranium (in terms of recoverable metal) was mined in 1956 in the USSR and its satellites, approximately 4,600 metric tons of which came from East Germany. The total figure is subject to a considerable uncertainty since we have no quantitative information on internal Soviet production for which we have assumed a value well within their capabilities. The estimated cumulative ore production through 1956 is more than sufficient to support the fissionable material production estimates.

41. *Future Uranium Ore Procurement.* The US Geological Survey estimates that the Soviet Bloc has several hundred thousand tons of uranium in medium grade ore deposits and an even greater quantity in low grade deposits. Many of these reserves are within the Soviet Union and could be exploited by present ore recovery methods. If it is assumed that the present estimated rate of expansion of ore production (see Table IV) is maintained through 1967, a reasonable estimate of Soviet Bloc ore production would be as tabulated below. We estimate that the actual cumulative production will not be less than three-quarters of the values shown and ore production could be considerably higher if desired. This estimate of Soviet bloc ore production will adequately support the estimated expenditure of natural uranium through mid-1967.

42. *Other Raw Materials.* There is evidence that the Soviet atomic energy program has exploited ores of thorium, zirconium, and other elements useful in atomic energy activities.

TABLE IV

URANIUM ORE PRODUCTION IN TERMS OF METRIC TONS RECOVERABLE URANIUM

Year	USSR	East Germany	Czechoslovakia	Bulgaria	Poland	Rumania	Hungary	China	Annual	Cumulative (Rounded)
Stocks Pre-1946	Nominal	200	65	Nominal					265	
1946	75	60	20	Nominal					155	400
1947	250	300	40	15	Nominal				605	1,000
1948	350	500	125	25	15				1,915	2,000
1949	450	1,000	200	50	40				1,740	3,750
1950	600	1,200	325	80	70				2,275	6,000
1951	850	1,700	350	85	75			Nominal	3,060	9,000
1952	1,150	2,400	425	125	75	30		25	4,230	13,000
1953	1,350	3,300	550	150	75	65		25	5,515	19,000
1954	1,500	3,800	675	200	75	100		45	6,395	25,000
1955	1,600	4,300	800	275	75	300		45	7,395	33,000
1956	1,600	4,600	1,000	275	75	340	Nominal	45	7,935	41,000
1957									9,000	50,000
1958									10,000	60,000
1959									11,000	71,000
1960									12,000	82,000
1961									13,000	95,000
1962									14,000	110,000
1963									15,000	125,000
1964									16,000	141,000
1965									17,000	157,000
1966									18,000	175,000
1967									19,000	195,000

Although little quantitative information is available, we believe that requirements for atomic energy purposes would represent only a small percentage of the supplies of these elements available to the Soviets.

43. *Economic Factors Affecting the Soviet Nuclear Program.* Economic intelligence was studied to evaluate the characteristics, magnitude and growth of the Soviet nuclear program. First, industrial studies were made of some of the basic materials flowing into the program, i.e., fluorspar, nickel powder, mercury, cement and steel to determine their availability to the nuclear program. Second, Soviet budget allocations were studied as indicators of the size and growth of the nuclear program.

44. *Commodity Estimates.* In all of the few cases where an evaluation has been made the estimated nuclear production requirements for particular commodities never exceed estimated supplies available for this purpose. To the contrary, available supplies of fluorspar and nickel powder sufficiently exceed estimated production requirements as to suggest the possibility of a larger Soviet nuclear production than has been estimated herein.

45. *Budget Allocations.* Available Soviet atomic energy budget information does not permit a definitive evaluation of the size and rate of growth of nuclear activities. Nevertheless, an analysis of the data indicate that the Soviet atomic program could be significantly larger than estimated herein. In particular, a preliminary analysis of possible cumulative nuclear investment allocations for the period 1945–1950 substantially exceeds estimated capital costs based on the physical size of the program indicated by all other intelligence.

46. *Uranium Metal Production.* Information obtained from returned German scientists, used in conjunction with data on calcium production and timetables pertaining to Soviet uranium metal plants permits a fairly reliable estimate of the amount of uranium metal ready for reactor use manufactured each year up through mid-1952. Analysis of this information indicates that: (a) the first metal suitable for reactor use was made at Elektrostal in early 1947; (b) this plant reached a capacity of 25 metric tons of uranium metal slugs per month by early 1950 and probably 50 tons per month by the middle of that year; and (c) production lines of 25 tons of slugs per month each went into operation at Glazov, west of the Urals, in September 1949 and mid-1950 and at Novosibirsk, in central Siberia, in late 1951 and mid-1952. No information is available on subsequent activities at these plants or at other possible uranium metal manufacturing facilities in the Soviet Union.

47. In the absence of post-1952 uranium metal plant information the subsequent production has been estimated on the basis of uranium ore procurement and an assumed ore reserve program. The USSR has had a State Reserve System since 1931 in order to create a planned reserve of a large number of essential raw materials and intermediate commodities to serve as a bulwark against either economic or military events. Soviet uranium ore procurement has exceeded uranium ore requirements by an amount which can be best explained in terms of the assumption of a State reserve to offset possible loss of supply. Comparison of the uranium ore estimate with independently derived estimates of uranium usage in the Soviet atomic energy program through 1953 strongly suggests that from 1946 through 1950 annual uranium ore procurement was kept at such a value as to maintain a three year reserve at all times, a pattern which is apparently repeated in the procurement of other materials for the atomic energy program. Post 1953 uranium metal production has therefore been estimated from the uranium ore procurement estimate on the assumptions that the three year reserve was maintained in the post 1950 period and that reactor tails were the sole source of feed for uranium isotope separation plants after mid-1953. In the table below, the uranium metal production for reactor use has been estimated from plant information up to mid-1953 and from the uranium ore estimate thereafter.

TABLE V

METALLIC URANIUM SLUG PRODUCTION

(Metric Tons)

Date	Production During Preceding Year	Cumulative Production
Mid-1947	25	25
Mid-1948	185	210
Mid-1949	240	450
Mid-1950	500	950
Mid-1951	1,200	2,150
Mid-1952	1,350	3,500
Mid-1953	1,800	5,300
Mid-1954	2,600	7,900
Mid-1955	4,300	12,200
Mid-1956	5,500	17,700
Mid-1957	6,400	24,100

TABLE VI

HEAVY WATER PRODUCTION

(Metric Tons)

Date	Production During Preceding Year	Cumulative Production
	Low	Low
Mid-1947		
Mid-1948	4	5
Mid-1949	15	20
Mid-1950	45	65
Mid-1951	55	120
Mid-1952	55	175
Mid-1953	60	235
Mid-1954	60	295
Mid-1955	65	360
Mid-1956	70	430
Mid-1957	70	500

48. *Heavy Water* (D_2O). Early in 1946 the Soviets began the conversion and installation of equipment at the Chirchik Nitrogen Combine in Central Asia to provide for the production of by-product heavy water for atomic energy uses. Simultaneously, Germany was exploited for heavy water, research results, equipment, and research personnel. About mid-1946 construction of production facilities to use the water electrolysis-catalytic exchange method was started at five other plants. Construction was also started on a seventh plant at Aleksin which used the hydrogen sulphide-water exchange method. Limited production commenced at Chirchik in 1947 and at Aleksin in late 1948. Most of the other plants began producing by 1949 or 1950. By late 1947 work was underway on a plant at Norilsk in far north Siberia using the ammonia-water exchange system. This plant probably did not begin heavy water production until early 1955. No other heavy water plants have been identified in the Soviet Union. Thus, although eight separate plants are now believed to be in operation, we estimate their annual heavy water production to be only about 70 metric tons per year.

49. The following cumulative estimate of heavy water produced in the USSR is considered to be reasonably accurate up through 1953. After mid-1953 the values given probably represent a minimum level of production.

50. *Graphite*. The Geneva and Moscow Conferences on Atomic Energy and evidence from returned German scientists have established that at least four Soviet research reactors, including their first one, used graphite as a moderating or reflecting material. Statements by I. V. Kurchatov, an important figure in Soviet reactor development, and information from returned German scientists indicate clearly that the first Soviet plutonium production reactor was also graphite moderated. The details of the manufacture and procurement of reactor graphite was still obscure, but it was apparently available as early as 1947.

51. *Lithium*. A number of Soviet tests have used lithium as thermonuclear fuel. [redacted] Several German scientists worked during their "cooling-off" period on the electromagnetic separation of lithium isotopes but they report that the project was undertaken at their own volition and excited no Soviet interest. It is probable that the Soviets are using a more economical method of separating lithium isotopes on a production scale. Their interest both in the procurement of lithium ores and of mercury in the post 1950 period suggests that they may be using the mercury amalgam method. We have no valid information on which to base an estimate of the amount of enriched lithium that might be available at any time, for

weapon use. We believe, however, that the quantity will be sufficient to meet requirements.

52. *Uranium-235 Production.*[12] The estimate of the timetable of initial Soviet U-235 production is well supported by information obtained primarily from returned German scientists. These data also permit a reasonably good estimate of U-235 production through mid-1953 based upon likely barrier availability and gaseous diffusion plant efficiency. Estimated Soviet production of U-235 after mid-1953 is based upon (a) estimates of electric power available for uranium isotope separation and (b) estimated operating efficiency of the Soviet uranium isotope separation plants.

53. The first Soviet gaseous diffusion uranium isotope separation plant was built at Verkhneivinsk in the Urals in the two years following the spring of 1947, and came into full operation during the latter half of 1949. A number of details of this plant have been furnished by returned Germans. It operated at very low pressures and utilized flat plate barrier with high permeability. The separation capacity of this barrier and the overall plant efficiency were poor. It was evidently designed to produce about 200 grams per day of 95% uranium-235, but in actual operation only turned out 70% material. The failure of this initial plant to achieve its design goal can be ascribed both to a Soviet overestimation of the performance of their flat plate barrier and to major corrosion and inleakage problems. This plant was reported to be still operating in 1953 probably producing small quantities of 70% material which could have been enriched to 90% in the much larger complex built in the post-1949 period at this site.

54. There is evidence that from 1949 on to the present time there has been a program to increase the basic efficiency of plant design. The corrosion and inleakage problems which were serious in 1949 were solved adequately by the end of 1950. Meanwhile plant construction, with newer designs incorporated, continued at Verkhneivinsk, and construction on a new site north of Tomsk in central Siberia started in 1949.

55. From mid-1949 to the end of 1952 the Soviets acquired large quantities of fine nickel wire mesh from East German and Soviet plants for use in the manufacture of a tubular barrier designed by German scientists then resident in the Soviet Union. Procurement of this mesh in East Germany was stopped at the end of 1952 but was resumed at a reduced rate in 1956. There is evidence that production continued within the USSR and possibly in Poland throughout this period. Other barriers not requiring mesh were developed, and at least one had successfully passed through the pilot plant stage by the end of 1952. The information on the quality and quantity of barrier made in the post 1952 period is, however, too limited to serve as a basis for estimation.

56. Although initial plant expansion at Verkhneivinsk in 1951 was designed for depletion to 0.3% U-235 concentration in the tailings, evidence from the German scientists indicates that it was operated at 0.5% at least until 1952. Furthermore, in view of the fact that there is an abundance of uranium ore available to the USSR, and that it is more economical from the standpoint of both kilograms of product per MW of electric power input and total quantity of output to strip to only 0.5%, the latter value has been used in all these U-235 calculations. The consistency of all necessary assumptions on plant design with the available evidence was established using basic gaseous diffusion theory. These studies establish not only that Soviet plants are designed differently from US plants, but that the Soviets have independently advanced their state of knowledge in the field of gaseous diffusion. However, the limited knowledge on the rate at which many of the design improvements investigated by the Soviets were incorporated into the operating plants necessitates a degree of uncertainty in the estimates of plant operating efficiencies.

[12] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

57. Our estimate of the Soviet gaseous diffusion program from mid-1950 to mid-1953 is based on [redacted] as well as on barrier fabrication methods and barrier quality parameters reported by returned Germans, and takes into account the Soviet improvements in plant design reported by returned Germans and moderate increases in compressor efficiency. (See Table VII.) According to this estimate, the Verkhneivinsk Complex produced the U-235 for the 18 October 1951 weapon test and attained a production rate of about four kilograms per day by mid-1953.

58. We estimate that by mid-1953 the Soviets had achieved an improved and fairly efficient gaseous diffusion process, some four (4) times more efficient than their earliest efforts. This evidence of increased Soviet capability has been extrapolated into the post-1953 period as a gradual improvement in the efficiency of utilization of electric power. These increases in efficiency can be predicted with some degree of reliability during the mid-1950's in terms of the application of improvements which the Germans helped develop through 1952. Beyond mid-1957, this extrapolation is an assumption of gradual progress achieved through improved barrier and compressors. [redacted]

59. A considerable amount of information on the generation and distribution of electric power in the Urals area has become available during the past year. The most important new evidence indicates that the majority of the power generated at the Nizhnyaya Tura power plant is being sent southward toward Verkhneivinsk. This leaves the function of the large atomic energy site near Nizhnyaya Tura in doubt and strongly suggests it does not manufacture uranium-235. However, the estimated electric power available to isotope separation for the current period (mid-1953 mid-1957) can be calculated with a fair degree of accuracy. This calculation is made by subtracting from the total power available in areas of probable Soviet gaseous diffusion plants that power estimated to be required for other industries, for export to other localities, and for local non-industrial uses.

60. Our estimate of future electric power allocations to isotope separation is fundamentally based on the assumptions that the Soviets will have expanding requirements for U-235 throughout the 1957–1966 period and will implement the production program necessary to meet these requirements. While these assumptions are consistent with available information, the extent of the actual expansion will depend on future Soviet decisions and actions which cannot be accurately predicted, and our estimates must have wide ranges of possible error. In arriving at these estimates, consideration was given to a variety of factors such as the planned future availability of electric power in regions of known isotope separation plants, the difficulties the Soviets are having in expanding their economy at the currently planned rate, and current evidence reflecting requirements for U-235 for military and nuclear electric power purposes.

61. The electric power estimated to be available for isotope separation through 1967 was arrived at by carrying forward the same proportion of new generating capacity devoted to gaseous diffusion isotope separation as that utilized in the period 1950–1956. The resulting value of 2,700 MW for the period from mid-1960 to mid-1961 is consistent with the midpoint of the range of electric power estimated to be potentially available at that time for isotope separation near Verkhneivinsk and Tomsk, and in the Irkutsk Oblast. The indicated expansion in the succeeding six years to 5100 MW, for example, is less than the total power to be available from the new, giant Bratsk Dam, in the Irkutsk Oblast. This value implies that in 1967 in the region from east of Lake Baikal to the western border of the Urals, gaseous diffusion plants will consume about 25% of the available electrical energy or 37% of the energy from generating capacity installed after 1956. However, this value is only 7% of the total planned electrical energy developed by the USSR in that year.

62. The uncertainty in the cumulative estimate of Soviet U–235 production through mid-1957, as shown in Table VII, is large but probably does not exceed a factor of two, i.e., one half to twice the stated quantity. However, the estimates of future production could be substantially greater or smaller than estimated, since these figures are based on assumptions of future Soviet capabilities and plans, and some of the latter may not yet have been decided by the Soviets themselves.

63. *U–235 Requirements of Power Program.* The amount of U–235 (90% equivalent) which the Soviets will sacrifice from their available weapon reserves has been obtained by estimating the fuel requirements for each planned reactor. The fuel requirements were determined by utilizing the intelligence data wherever possible supplemented by operational information obtained from known reactors of the same type. Soviet statements have indicated an expansion of 25,000 megawatts by 1985. For purposes of calculation, we have assumed an average expansion of 600 EMW per year for the first six years of the expanded nuclear power program, 1961 to 1967.

63a. In Table VIII, the annual fuel requirements have been appropriately allotted on the basis of assumed Soviet practice to provide an indication of probable uranium-235 expenditure in the power reactor program. The cumulative estimate of 90% U–235 equivalent presented in Table VIII as expended or tied up in the nuclear power reactor program is subject to considerable variation depending on Soviet plans for different reactor designs, the date each reactor is placed in operation, and the method and schedule of fuel reprocessing.

64. *Production Reactors.* There is evidence that construction on the first Soviet produc-

TABLE VII

ESTIMATED SOVIET PRODUCTION OF URANIUM 235 [13]

Date Mid-Year	Estimated Annual Average Electric Power Available to U–235 Production Sites: Year Preceding MW [14]	Estimated Average Efficiency of Electric Power Utilization MWD/KG	Estimated on Stream Time in %	Cumulative Production KG 90% U–235 rounded
1949				
1950	50	[15] 246	75	50
1951	90	[15] 105	80	280
1952	150	[15] 65	85	900
1953	250	[15] 63	90	2,100
1954	385	60	95	4,100
1955	585		95	7,300
1956	785		95	12,000
1957	1,110	50	95	18,000
1958	1,500		[16] 100	28,000
1959	1,900		100	42,000
1960	2,300		100	59,000
1961	2,700		100	80,000
1962	3,100	40	100	106,000
1963	3,500		100	136,000
1964	3,900		100	172,000
1965	4,300		100	213,000
1966	4,700		100	260,000
1967	5,100	32	100	312,000

[13] See footnote 3, page 2, for the position of the Director of Naval Intelligence.
[14] It is assumed 90% of this electric power available to production sites was used within the diffusion cascade itself.
[15] Factor derived from electric power estimate divided by the production rate calculated from barrier information.
[16] Downtime after 1957 is considered to be negligible.

TABLE VIII

ESTIMATED USE OF U-235 BY THE SOVIET POWER PROGRAM [17]

Date	Total EMW Installed	Cumulative Loss, 90% U 235, (Loss & Inventory)
Mid-1958	5	
Mid-1959	415	700
Mid-1960	1,155	2,010
Mid-1961	1,400	3,010
Mid-1962	1,800	4,490
Mid-1963	2,400	6,580
Mid-1964	3,000	8,060
Mid-1965	3,600	10,840
Mid-1966	4,200	14,100
Mid-1967	4,800	17,750

[17] The average initial inventory for each large reactor was calculated to be equivalent to about 350 kilograms of 90% U 235. The average annual consumption of 90% U-235 by each large reactor was calculated to be equivalent to 130 kilograms. The requirements of the experimental stations are very small and therefore are not included.

tion reactor started early in 1947 near Kyshtym in the Urals and that it went into operation about mid-1948. Statements by returned Germans and from I. V. Kurchatov strongly indicates that this reactor was similar in some respects to the early Hanford models. The reactor reportedly was water cooled and graphite moderated, used about 100 metric tons of uranium, and had about 1,000 vertical fuel channels. It probably developed about 100 megawatts of heat power initially but may later have been raised to much higher power levels as has been the case in US experience. The urgency of the Soviet program during this period is perhaps reflected in the fact that construction of this reactor was underway some six months before the USSR's first research reactor (also graphite moderated) went critical in the late summer of 1947.

65. There is information that a heavy-water moderated reactor went into operation at Kyshtym sometime toward the end of 1949. Construction of this reactor probably began about the same time construction was initiated on the heavy-water research reactor which became operational in April 1949 at the Thermo Technical Laboratory in Moscow. Continuing Soviet production of heavy water indicates that subsequent heavy-water production reactors must have been built, but [redacted] and the availability of uranium metal through 1952 both indicate that post 1949 reactor construction in the Soviet Union was not limited to heavy water reactors alone.

66. The exact schedule of reactor construction after 1948 is not known. Deductions from estimated uranium metal availability, heavy water production, and site timetables suggest that five or six production reactors were constructed at Kyshtym by mid-1952, of which two or possibly three were heavy-water moderated. There is evidence that a second reactor site went into operation in the area of Krasnoyarsk, probably in 1953. The estimated availability of uranium metal and heavy water in 1953 and later suggest that two or three large heavy-water moderated reactors have been built since 1952, presumably in the Krasnoyarsk area.

67. Initially the separation of plutonium from uranium and fission products was done by an oxidation-reduction-co-precipitation process which differed somewhat from that initially adopted by the US. It was planned to recover uranium as well as plutonium, since the uranium metal plant at Glazov was designed to process reactor depleted uranium as partial feed material. Soviet and German research on solvent extraction and other methods indicates that the Soviets may have later developed a better process. However, Soviet interest in solvent extraction methods at the 1955 Geneva Conference on Atomic Energy, and their subsequent publication of rather elementary studies of a solvent extraction method suggest that they may still have been using their initial process as late as 1956.

68. *Plutonium Equivalent Production.*[18] [redacted]

[18] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

[redacted]

69. [redacted]

70. Evidence from various aspects of the Soviet atomic energy program suggests, however, that a significant expansion of Soviet plutonium equivalent production has taken place sometime since mid-1953. Soviet procurement of raw materials for fissionable material production, particularly uranium ore and fluorspar, has continued to increase. Although this procurement increase does not necessarily indicate corresponding and proportional increases in fissionable material production, the quantities of raw material apparently accumulated are not consistent with a constant level of plutonium production, even when the estimated large increase of U-235 production since mid-1953 is taken into consideration. There is also evidence that a second Soviet production reactor site was built in the Krasnoyarsk area of central Siberia and [redacted] The extensive use of plutonium in Soviet nuclear tests, particularly in the 1956 thermonuclear tests, while explicable on technical grounds, suggests that the Soviets would have increased the production of plutonium equivalent.

71. Assuming that the Soviets expanded plutonium equivalent production after mid-1953, it is difficult to tell when this expansion took place, [redacted]

72. Our estimate is based on the assumption that the Soviets gradually expanded plutonium equivalent production beginning in 1954. The estimate has been derived from estimated uranium ore procurement and assumed stockpiling practices; estimated feed practices in U-235 separation plants; estimated heavy water and uranium metal production; estimated site construction time schedules; deductions and assumptions on Soviet reactor designs and [redacted] The accuracy of the resultant estimate of plutonium equivalent production is particularly dependent upon the validity of the reactor irradiation time estimate, the uranium ore estimate, the use of reactor tails only in separation plants since 1953, and the estimate of uranium ore stockpiling practice.

73. Our estimate of Soviet plutonium equivalent production is based on an expanding program [redacted]

TABLE IX

PLUTONIUM EQUIVALENT PRODUCTION TO MID-1956[19]

(*Kilograms*)

Date	Estimated Cumulative Production
Mid-1949	6
Mid-1950	42
Mid-1951	190
Mid-1952	425
Mid-1953	770
Mid-1954	1,380
Mid-1955	2,350
Mid-1956	3,900
Mid-1957	5,600

[19] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

74. *Future Plutonium Equivalent Production.* We estimate that the USSR will continue to place a high value on plutonium equivalent and to make a considerable effort to produce large quantities of it. The Soviet production from 1957–1959 has been estimated on the same basis as for the 1953–1957 period. Starting in 1959 we assume that all new plutonium equivalent production capacity will come from the power reactor program.

75. *Plutonium Production by Power Reactor Program.* [redacted] The suitability of the plutonium for some types of weapons will decrease with an increase in the duration of the reactor operating cycles, however, the shorter the cycle the greater the operating cost. The Soviets have stated that the plutonium produced in the power program could conceivably be reprocessed and utilized as reactor fuel in an attempt to make the nuclear power program as self-sufficient as possible with regards to fuel. It is believed that this concept was discussed for its psychological effect but that it would not be adopted because plutonium is more valuable in the weapons program.[20] The major impact of the nuclear electric power program on future fissionable material stockpiles, either as a consumer of U–235 or as a producer of plutonium, will depend after 1961 upon the results of the planned program through 1960. Table X gives the estimated total installed electrical megawatts and the plutonium production of the nuclear power program.

TABLE X

ESTIMATED PRODUCTION OF PLUTONIUM BY THE SOVIET POWER PROGRAM

Date	Total EMW Installed	Annual Production (*Kilograms*)	Cumulative Production (*Kilograms*)
Mid-1958	5		..
Mid-1959	115	..	..
Mid-1960	1,155	200	200
Mid-1961	1,400	500	700
Mid-1962	1,800	600	1,300
Mid-1963	2,400	800	2,100
Mid-1964	3,000	1,100	3,200
Mid-1965	3,600	1,400	4,600
Mid-1966	4,200	1,700	6,300
Mid-1967	4,800	2,000	8,300

76. The estimate tabulated below includes plutonium from both production and power reactors. It must be recognized that the uncertainties about future Soviet plans introduces large errors into the future production estimates and that these errors increase rapidly as the estimate is extended into the future. It is not believed that a meaningful numerical range of this uncertainty can be given after mid-1957.

[20] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

TABLE XI

ESTIMATE OF TOTAL PLUTONIUM EQUIVALENT PRODUCTION [21]

Mid-Year	Cumulative Production (*Kilograms*)
1957	5,600
1958	7,600
1959	10,000
1960	12,600
1961	15,500
1962	18,500
1963	21,700
1964	25,250
1965	29,000
1966	33,100
1967	37,500

[21] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

77. *Tritium.*[22] The first known Soviet interest in tritium was revealed by the publication in late 1948 of a comprehensive review of the literature on tritium by M. B. Neyman, a staff member of the Soviet atomic energy authority. Returned Germans report that by 1952 tritium was available for research in their laboratories. [redacted] We estimate that tritium availability up to mid-1959 would not be more than 10% of the total plutonium equivalent and after mid-1959 that tritium production be limited to 20–50% of production reactors' and 5% of power reactors' capacity for plutonium production.

78. *Uranium-233.*[23] Active Soviet interest in thorium-bearing minerals started about mid-1946 with the formation of a special directorate for their exploitation. Although part of this interest lay in the requirement for lanthanum which is found in thorium-bearing minerals and was needed for the Soviet plutonium separation chemical plant, German scientists at Elektrostal were also required to design a process for the production of pure thorium oxide. Subsequently, the USSR acquired considerable thorium stocks. However, until the appearance of U-233 in the high-yield test of 22 November 1955, the only certain production of U-233 from thorium was the research quantities mentioned at the Geneva and Moscow Conferences on Atomic Energy. There has been no detected weapon use of U-233 since the November 1955 shot, and it appears probable that the Soviets are not making important quantities of U-233 for weapon stockpiling at present. The interest in thorium breeder reactors in their power reactor program suggests a possible future weapon utilization of the material.

79. *Future Fissionable Materials Available for Weapon Uses.* The estimated cumulative quantities of fissionable material available for weapon uses are tabulated below. The amounts have been calculated by deducting

TABLE XII

ESTIMATED FISSIONABLE MATERIALS AVAILABLE FOR WEAPON USES [24]

(*Kilograms*)

Mid-Year	U-235	Plutonium Equivalent
1949		6
1950		35
1951	...	180
1952	825	410
1953	2,000	750
1954	3,850	1,350
1955	7,000	2,300
1956	11,500	3,800
1957	17,500	5,500
1958	27,500	7,400
1959	41,000	9,800
1960	56,000	12,400
1961	77,000	15,300
1962	101,000	18,300
1963	129,000	21,500
1964	163,000	25,000
1965	202,000	28,800
1966	245,000	32,900
1967	294,000	37,300

[24] See footnote 3, page 2, for the position of the Director of Naval Intelligence.

[22] For planning purposes the production of 1 gram of tritium is equivalent to the production of 100 grams of plutonium.

[23] For planning purposes the production of 1 gram of uranium-233 is equivalent to the production of 1 gram of plutonium.

from the estimated production those quantities of fissionable material estimated to meet pre-1957 nuclear test expenditures, and to meet the inventory and fuel requirements of research and power reactors. No deductions have been made for production reactors expenditures, future nuclear tests, propulsion applications of fissional materials, or materials tied up in weapons manufacturing pipelines. If a major nuclear propulsion program were undertaken, this would require substantial allocations of fissionable material.

VII. SOVIET NUCLEAR WEAPONS

80. *Nuclear Tests.* The first Soviet nuclear test was conducted in 1949, at the main Soviet proving ground in the vicinity of Semipalatinsk, and was followed by tests in 1951, 1953, 1954, 1955, 1956 and 1957. A total of 35 tests have been detected in which plutonium, uranium-235, and in one instance uranium-233 have been used as the fissionable materials. As many as nine of the tests may have been directed toward the development of thermonuclear weapons.

81. *1949 and 1951 Nuclear Tests.* The August 1949 test explosion apparently was conducted as soon as sufficient plutonium was available. It utilized an all-plutonium core, yielded approximately 20 kilotons (of TNT equivalent), had a relatively low efficiency, and apparently closely resembled the first US implosion weapon. The two test explosions in 1951 demonstrated a marked increase in the efficiency of utilization of fissionable material. [redacted] The second of these tests, JOE 3 with a composite core, revealed that the USSR had been able to produce weapon grade U-235 in kilogram quantities.

82. *1953 Nuclear Tests.* The four explosions in 1953 demonstrated that the USSR was seeking to supplement the medium-yield weapons tested in 1951 by the addition of both high-yield weapons and low-yield, smaller diameter weapons. JOE 4, a [redacted] thermonuclear device detonated on 12 August 1953, yielded about 300 kilotons. The thermonuclear material used in this device was lithium deuteride. [redacted]

83. *1954 Nuclear Tests.* Seven explosions occurred in 1954. The first, which took place near Totskoye, we estimate to be an airdrop of a nuclear weapon as part of a military exercise and weapons effects test. The remaining six tests occurred at the main Soviet proving ground in the vicinity of Semipalatinsk. All tests of this series yielded 100 kilotons or less. [redacted]

84. *1955 Nuclear Tests.* Five nuclear detonations occurred in 1955. JOE 17, on 21 Sept. 1955 was the only Soviet nuclear explosion known to date to have occurred under water. The JOE 18 test yielded about 200 kilotons, and is considered to have been the airburst of a weaponized version of the JOE 4 device. [redacted] A development of great significance was JOE 19, the airburst on 22 November 1955 of a thermonuclear weapon which yielded about 1.7 megatons. It is highly probable that this [redacted] marked the effective beginning of a Soviet multi-megaton nuclear weapon capability. Another test, JOE 16, may have been detonated at a high altitude [redacted]

85. *1956 Nuclear Tests.* The 1956 Soviet nuclear tests are particularly significant. Tests extended throughout the entire year, from 2 February until 14 December, and included 9 nuclear detonations. [redacted]

[redacted] JOE 24 and JOE 27 were air burst tests yielding 2.2 and 2.7 megatons respectively. [redacted]

86. *1957 Nuclear Tests.* The 1957 tests began with a detonation on 19 January 1957 at 50° N., 48° E., about 100 miles NNE. of Kapustin Yar. This air burst yielded about 4 kilotons. The facts that the test was a relatively low air-burst, was detonated near a Soviet guided missile test center, but not on the ballistic missile test range, and was completely removed from any previous nuclear test location, suggest the test of a nuclear warhead in a missile, possibly an air-to-surface type. The next test, which was conducted on 8 March 1957 at the Semipalatinsk test site, yielded 15 KT, was an air-burst, [redacted] Commencing 3 April, five detonations occurred in fourteen days. All of the tests took place at the Semipalatinsk site. These tests occurred too late to permit complete analysis prior to publication of this estimate. Preliminary information indicates the yields were as follows: (a) 3 April, 70 KT; (b) 6 April, 70 KT; (c) 10 April, 1,300 KT; (d) 12 April, 30 KT; and (e) 16 April, 750 KT.

TABLE XIII

EVALUATION OF SOVIET NUCLEAR TESTS

No.	Date	Burst Height (ft.)	Yield (KT)	
JOE 1	29 Aug 49	Surface	20	[redacted]
JOE 2	24 Sept 51	Surface	30	
JOE 3	18 Oct 51	Air	15	
JOE 4	12 Aug 53	Surface	300	
JOE 5	23 Aug 53	Air	25	
JOE 6	3 Sept 53	Air	8	
JOE 7	10 Sept 53	Air	8	
JOE 8	14 Sept 54	1,000-5,000	35-100	
JOE 9	3 Oct 54	Air	4	
JOE 10	5 Oct 54	Possibly over 20,000	15	
JOE 11	8 Oct 54		20	
JOE 12	23 Oct 54	Air	90	
JOE 13	26 Oct 54	Probably Air	7	
JOE 14	30 Oct 54	Air	25	
JOE 15	29 Jul 55		4	
JOE 16	2 Aug 55	Possibly over 20,000	30	
JOE 17	21 Sept 55	Underwater	~20	

See footnotes at end of table.

TABLE XIII (*Continued*)

No.	Date	Burst Height (ft.)	Yield (KT)
JOE 18	6 Nov 55	1,500-8,000	200
JOE 19	22 Nov 55	3,000-10,000	1,700
JOE 20	2 Feb 56	Air	~20
JOE 21	16 Mar 56	Surface	30
JOE 22	25 Mar 56	Surface	25
JOE 23	24 Aug 56	Surface	60
JOE 24	30 Aug 56	2,000-4,000	2,200
JOE 25	2 Sept 56	>1,500	100
JOE 26	10 Sept 56	1,500-3,000	90
JOE 27	17 Nov 56	4,000-8,000	2,700
JOE 28	14 Dec 56	Air	25
JOE 29	19 Jan 57	Air	~3.5
JOE 30	8 Mar 57	Air	15
JOE 31	3 Apr 57	Probably Air	70
JOE 32	6 Apr 57	Probably Air	70
JOE 33	10 Apr 57	Possibly Air	1,300
JOE 34	12 Apr 57	Possibly Air	30
JOE 35	16 Apr 57	Possibly Air	750

~Approximately.
<Less than.
>Greater than.

87. No direct information is available on the specific nuclear weapons types in the USSR stockpile. However, Soviet nuclear tests have indicated that several types of weapons have been proof-tested, and such weapons types are probably included in the present stockpile.

88. In Table XIV are listed the estimated present and future Soviet nuclear weapons development capabilities. The characteristics of the weapons estimated to have been proof-tested have been derived from the nuclear test data making reasonable specific choices of yields, diameters, weights, and quantities of fissionable materials in cases where the test data indicate a range of possible values. The characteristics of the other weapon types estimated to be available to the Soviets at the present time have, in general, been derived from the proof-tested weapons, other tests, and substitute designs which are considered to be well within Soviet capabilities.

89. *Current Fission Weapons.* It is estimated that the current Soviet nuclear weapons stockpile could contain fission weapons [redacted] we believe that the Soviets possess the capability required to produce fission weapons with a wide range of dimensions and yields, [redacted]

90. *Current Thermonuclear Weapons.* [redacted] The 1956 nuclear tests included a number of thermonuclear devices, and weapons based on these tests could become available in the 1957 period. [redacted]

91. *Gun-Assembly Weapons.* Although the USSR is not known to have tested nuclear weapons employing gun-type assembly, it is considered that, because of the simplicity of design, weapons of this type could now be available in stockpile. [redacted] However, in view of the lack of test evidence, we estimate that the Soviets will not stockpile such weapons in quantity because of the large fissionable material requirement.

92. [redacted]

93. *High-Yield Missile Warheads.* In NIE 11-5-57 we have estimated that the Soviet guided missile program has design and successfully tested a missile with a range of about 700 miles and a CEP of approximately 2 nautical miles. We have estimated that this missile can carry a warhead weighing 6,000 pounds. This Soviet requirement for a high-yield, 6,000 pound warhead has been considered in interpreting data from thermonuclear tests, [redacted]

94. Any prediction of future Soviet weapons development must be made by extrapolating estimates of present Soviet capabilities and by evaluating the estimated military requirements of the USSR and the apparent gaps in the Soviet nuclear test program. As in our assessment of earlier Soviet weapon designs, US nuclear weapons technology has been used as a guide in evaluating future Soviet weapons capabilities, in order to permit rough estimates of the capabilities of the USSR in the

post-1957 period. [redacted] Outmoded weapons will be replaced in the stockpile by more efficient and economical designs as these become available. Consequently, the composition of the USSR nuclear weapons stockpile at some future date is extremely uncertain.

95. *Future Thermonuclear Weapons.* [redacted] While the 1956 USSR thermonuclear tests appear to use pure plutonium in the weapon primary, the use of composite primaries of plutonium or uranium-233 with uranium-235 is considered within Soviet capabilities. [redacted]

96. *Boosted Nuclear Weapons.*[27] [redacted] depend upon the successful application of tritium gas boosting. [redacted] This technique will permit the development of smaller diameter thermonuclear weapons, the development of pre-initiation proof weapons and the more efficient use of fissionable materials in low-yield devices. [redacted] Furthermore, since tritium is subject to radioactive decay with a half-life of 12 years, we estimate that production and stockpiling of large quantities of tritium will not begin until the Soviets have achieved a satisfactory test of the gas-boosting technique. Thus production of [redacted] weapons [redacted] will be limited by the stockpile of tritium available at the time of production, and calculation of the stockpile quantities of these weapons should be limited by the quantities of tritium in current production during the 1960–1961 period. Since the production of tritium in reactors is competitive with production of plutonium, it is also assumed that an economy in the use of plutonium will be practiced in this period for any weapon in which uranium-235 can replace plutonium for the fissionable core.

[redacted]

97. *Fission Yield from Soviet Thermonuclear Weapons.* We can only determine within very broad limits the ratio of the fission yield to the total yield for the large Soviet thermonuclear weapon tests. [redacted]

98. *Nuclear Weapons Development After 1961.* We have no basis for estimates of Soviet nuclear weapons development in the post-1961 period. In general, we anticipate that the USSR will be capable of producing nuclear weapons of the range of yields and characteristics required for support of Soviet military requirements. [redacted] In addition to thermonuclear weapons, a wide variety of fission weapons, including very small low-yield weapons, will be available to meet various requirements.

99. *Requirements for Continued Testing in the Soviet Nuclear Weapons Program.*[25] The Soviet test program has already provided sufficient data for the rapid and successful development of a variety of nuclear weapon types. The majority of the 35 Soviet nuclear detonations detected by the US appear to have been primarily weapons development tests, although military interest in weapons effects tests is evident in the Totskoye test of 1954 and the Novaya Zemlya underwater test in 1955. We believe that the Soviets will stockpile, in significant numbers, only weapons employing tested design principles. Major improvements in weapon design, which result in significant changes in anticipated yield, or new weapons designs and concepts will probably be tested before stockpiling.

100. *Thermonuclear Weapons Tests.* Eight or nine of the 35 detected Soviet nuclear tests probably involved detonation of thermonuclear weapons or devices with thermonuclear weapons design principles. These tests have provided sufficient design data to permit Soviet stockpiling of thermonuclear weapons with yields up to a few megatons of TNT equivalent. [redacted]

[25] See SNIE 100-7-56, "Effect of A Test Moratorium On The Soviet Weapons Development Program," [redacted] 13 November 1956.

101. *Boosted and Low-Yield Weapon Tests.* Increasing the efficiency of utilization of fissionable material in low-yield weapons by the addition of fissionable material, a technique called "boosting," [redacted] Additional low-yield nuclear tests will probably be considered desirable to verify the reliability of such nuclear weapons when adapted to specific delivery systems.

VIII. NUCLEAR PROPULSION

102. *Application of Nuclear Propulsion for Aircraft by the USSR.* There is no evidence of Soviet activities directly identified with a program for nuclear aircraft propulsion. However, the Soviets have made increasingly frequent references to the feasibility of aircraft [redacted]

nuclear propulsion during the past year. These have ranged from popular discussions in newspapers and magazines to statements by some of the highest officials in the USSR. It is believed that the amount of discussion permitted on this subject reflects Soviet confidence that they will be able to develop a practical system of aircraft nuclear propulsion. Some of the research known to have been conducted by the USSR could apply appropriately to nuclear propulsion for aircraft. It is assumed that a nuclear propulsion reactor research program for aircraft began when it was realized by the USSR that certain reactors could be utilized for this purpose. We estimate that:

(a) The Soviet aircraft nuclear propulsion reactor program is probably now engaged in development and testing of reactor components and sub-systems.

(b) A reactor system suitable for nuclear propulsion of subsonic aircraft could probably be available to the Soviets in 1962.

103. Intelligence indicates that the USSR has considered the feasibility of nuclear propulsion for missiles. At least preliminary design studies have been conducted for a nuclear propulsion system but a nuclear reactor program for missile propulsion has not been identified. The Soviets have openly published a paper describing in general terms a reactor system for missiles which appears to be technically sound. We estimate that the USSR has, at most, conducted basic research on developmental components for such a system.

104. *Naval and Marine Applications of Nuclear Propulsion by the USSR.* The Soviet Union exhibited an interest in nuclear ship propulsion as early as 1948. Publications and statements in 1955 and 1956 have confirmed this interest, which has been extended to include nuclear-powered submarines, transports, large cargo ships, tankers, factory whaling ships, and the highly publicized icebreaker now under construction at Leningrad. There is no doubt that a nuclear propulsion reactor suitable for naval and marine applications is currently under construction. On the basis of the current state of Soviet reactor research and development, the status of the icebreaker construction, together with related time scales derived from US experience, we estimate that:

(a) A nuclear propulsion reactor for a surface ship (icebreaker) will be installed in early 1958, and that the ship will undergo operational tests in late 1958 or early 1959.

(b) A nuclear propulsion reactor for a submarine could be available for installation in 1957.

(c) That by the time these ships complete operational tests, the Soviets could undertake the construction of a variety of surface ships and submarines.

105. The reactors employed in the first surface ship and submarine will probably be of a pressurized water type and use enriched fuel. The Soviets have considered other types of reactors for propulsion purposes, specifically the liquid-metal, the gas-cooled, the fast breeder and the homogeneous-boiling types. The first two mentioned could be adapted to surface ship propulsion in the near future; we believe that the Soviets could construct one or both these types of reactors for surface ships by 1960. Until 1960, the reactor most likely to be used in a submarine propulsion system is the pressurized-water type. Soviet reactor engineers have stated that homogeneous-boiling water reactors may be the best type for marine propulsion. This type reactor could be adapted to both submarine and surface ship propulsion after 1960.

IX. INTERNATIONAL ACTIVITIES

106. *Soviet Aid to Bloc Nuclear Research.* The Soviet Union has continued in her role as an active participant in international atomic energy activities. The program of aid to the Bloc (the furnishing of 2 to 6.5 MW, slightly enriched, swimming pool-type research reactors, particle accelerators, radioisotopes and technical training of personnel) as announced in January 1955 is still in progress. Construction of the physical facilities to house the reactors is underway in the Bloc countries. Delivery of the actual reactors is scheduled for 1957. Bloc scientists have gone to the Soviet Union for training and Soviet scientists have come to the Satellites to lecture on atomic

energy for peaceful purposes. Shipments of radioisotopes have been made to all of the Bloc countries. Exhibits similar to the one displayed at the Geneva Conference in August 1955 have been sent by the Soviet Union to several of the Satellites. These exhibits have also been sent to India, Sweden and Yugoslavia.

107. *Soviet Offers of Power Reactors.* The Soviet aid program has been expanded to include assistance to the Satellites in the construction of reactors for the production of electric power. Czechoslovakia, East Germany, Hungary and Rumania have reported plans for Soviet assistance in the construction of 100–200 MW reactors within the next five years.

108. *The Joint Nuclear Research Institute.* The Joint Nuclear Research Institute, located at Dubna near Moscow, was created in 1956 to serve as the focal point of Sino-Soviet Bloc technical cooperation in nuclear energy. The primary functions of the Institute appear to be: (a) to coordinate and guide joint theoretical and experimental nuclear research in the Bloc; (b) to exploit the potentialities of the Bloc nuclear scientists; (c) to train Bloc scientists in the use of equipment such as particle acelerators and experimental reactors; and (d) to minimize the attraction for Bloc scientists in participation in non-Communist nuclear research centers. All Sino-Soviet Bloc countries have membership in the new organization. The dominating role of the Soviet Union is reflected by the physical location of the Institute, the control exercised over the activities, and the annual financial contribution to the operation and expansion of the Institute. Some of the Bloc countries have indicated concern that membership in the Institute will result in Soviet domination over the direction of any research and Bloc scientists will not be free to follow projects of their own choosing. It has been publicly stated that participation in the work of the Institute will be open to non-Bloc countries.

109. *Soviet Aid to Non-Bloc Countries.* The most extensive aid agreements to non-Bloc countries have been made with Yugoslavia and Egypt. Yugoslavia is scheduled to receive a 6.5 MW research reactor and other technical aid similar to that given to the Satellites but negotiations concerning terms for delivery broke off without agreement in early 1957. Egypt is to receive a 2 MW research reactor, research equipment, training and assistance in a geological survey for uranium ore. In October 1956, Shigeharu Shimura, a member of the Japanese Joint Committee for Atomic Energy was informed by Nesmeyanov, President of Academy of Sciences and Slavsky, Chief Main Administration for Atomic Energy, that Japan could receive atomic reactors, atomic fuel and other technical aid if formal agreements concerning technical interchange between the USSR and Japan would be concluded. In these discussions the Soviet representatives reportedly stated that they have no intentions of attaching to their technical aid any conditions as may restrict or encroach upon the rights of the other party. There has been no evidence of any actual negotiations between the Soviet Union and the Japanese government having taken place as yet. The Soviet Union has made general statements both from Moscow and in speeches in New York at the Conference on the Statute of the International Atomic Anergy Agency, criticizing control provisions of the Statute and of US bilateral agreements as imposing political and economic conditions inconsistent with the sovereign rights of nations. While terms on which the Soviets supply nuclear materials have not been published, the Soviets allege that they impose no restrictions on the use of the material or its disposition. Limited offers of training and supplies of radioisotopes have been made to India, Iran, Indonesia, Lebanon, Syria, Thailand, Greece, and Burma. Soviet moves in the Western Hemisphere have been noted in steps being taken to obtain an exchange of Mexican professors and students. The Soviets have also attempted to provide Chile with nuclear research equipment through the United Nations Technical Assistance Administration. Offers of material and aid, thus far rejected, have been made to Norway and Austria.

110. *Soviet Moves Directed Against the West.* Many of the Soviet moves in international activities in the atomic field have been obvious attempts to counteract Western developments. In July 1955 the Soviets called a conference on the peaceful uses of atomic energy probably as an attempt to detract from the United Nations sponsored Geneva Conference in August 1955. In July 1956 the Soviets proposed the formation of a General Regional Body for Peaceful Uses of Atomic Energy to include all the East and West European countries and the United States. The announced purpose of the Body was to foster interchange of information and provide mutual assistance in the peaceful uses of atomic energy. This organization was proposed at a time when West European countries were considering the EURATOM and OEEC plans and appears to have been an attempt to cause dissent among the Western European countries involved in the EURATOM and OEEC discussions. The Joint Nuclear Research Institute might be considered to be an East European counterpart to CERN, the Western European Institute at Zurich. The Joint institute will have far more extensive facilities available to its members.

111. *International Conferences and Soviet Visits to the West.* Attendance of Soviet scientists at international conferences and visits of Soviet scientists to Western countries have continued to increase. In addition to participation in Western meetings the Soviets have called conferences in the Soviet Union with invitations to the West. The most important of these was the USSR Conference on High-Energy Physics in May 1956 in which US and other free-world scientists participated. There were two particularly significant Soviet visits made to the West during the past year. The first was Kurchatov's visit to Harwell, England, in April 1956 where he openly discussed Soviet work in the field of controlled thermonuclear reactions and, in addition, gave considerable details of the Soviet power reactor program. The second was Artsimovich's visit to Sweden in July 1956. His discussions of controlled thermonuclear reaction experiments were more revealing than the statements made by Kurchatov.

112. *The International Atomic Energy Agency.* The Soviet Union played an active part in the recent Conference on the Statute of the International Atomic Energy Agency held at the United Nations headquarters in New York. The Soviets made no constructive contribution to the Statute of the Agency; their principal effort was to make a record in favor of (a) Red Chinese participation in the Agency; (b) technical aid being free of any conditions which infringe on the sovereign rights of the recipient; and (c) a place for Soviet Satellites in the management of the Agency. Although the Soviet Union voted for the Statute as finally adopted by the Conference on October 26, 1956, the Soviet Union has made no commitment for support of the agency beyond a promise in its note of 18 July 1955 to supply 50 Kg of fissionable material. Their principal interest appears to be the propaganda and political aspect of the Agency's activities.

113. *Effects of Unrest in the Bloc Countries.* It is not possible as yet to determine the full extent of the impact that the Polish and Hungarian uprisings will have on Soviet atomic aid to the Bloc. The Soviet-Czech agreement issued January 29, 1957, provides for continued Soviet atomic energy assistance, and also for continued and expanded supply of Czech uranium ore to the USSR. In Hungary there has been evidence of dissatisfaction on the part of a Hungarian official with the price being asked for the research reactor, labeled by the official as obsolete. Nevertheless, the Hungarian State Investment Plan for 1957 states that the research reactor will be completed during the year. Poland has recently made overtures to the United States for atomic aid. This is the first such move by a Satellite nation. Another example of a more independent attitude on the part of Bloc nations is the increasing interchange of scientific visits among the Satellites and between Bloc scientists and Yugoslav scientists.

114. We estimate that the Soviet Union will continue to participate in international atomic energy affairs. Her aid to Bloc countries and offers of aid to non-Bloc countries will continue for political and propaganda purposes. By 1959 the Soviet Union will probably make further offers of aid in the construction of atomic power stations to non-Bloc countries when its first full scale plant goes into operation.